POSTURAL CONTROL AND COGNITIVE FUNCTION

by

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(Under the Direction of Phillip Tomporowski)

ABSTRACT

The purpose of the study was to investigate the impact of balance disruption induced by wearing a weighted backpack on the cognitive functions of volunteers recruited from the UGA Army and Air Force ROTC. Participants performed a dual task protocol, consisting of a balance task on the NeuroCom Smart Balance master and an auditory switch-task, with or without an additional 30% body weight load. A significant main effect for balance data was found for both load type and balance condition. Main effects were found for the proportion of participants' errors scores for load type. An interaction between load type and task type was identified. Dual-tasking methodologies suggest military personnel can maintain the timing of executive processes despite increased disturbance in balance; however, the accuracy of their responses may decrease their effectiveness in the field.

INDEX WORDS: Posture, Stability, Balance, Cognitive, Reaction, Military, ROTC

BALANCE DEMANDS AND COGNITIVE FUNCTION

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INTRODUCTION

Military personnel are often required to carry heavy loads for long distances over unpredictable terrains. Load carriage and long distance marches are a significant aspect of training and operations. In some operations, soldiers are required to carry 75-134 lbs. over 6-12 mile distances (Knapick, 2004). Military personnel must also be able to perform challenging critical military task during and after long distance marches that consist of maintaining efficient body movement while simultaneously performing a cognitive task (e.g., backpacking in a rough terrain while listening to route directions).The demands placed on the military personnel's systems by the load carriage, environmental demands, and cognitive task can directly or indirectly result in reduced performance, deaths, and disastrous engagements.

The loads carried by military personnel can change the biomechanics of their posture. Military personnel must learn to control posture while carrying heavy loads in order to have efficient movement through changing terrain. Postural control is the control of the body's position in space for the purpose of balance and orientation while in static and dynamic conditions (Latash, 2008). Postural sway reflects the interaction between destabilizing forces acting on the body and actions by the postural control system to prevent a loss of balance. The postural control system is composed of several sensory systems that are hierarchically ordered, including the visual, vestibular, and somatosensory systems. Vision aids balance by providing information concerning where the body is in space and the direction of motions. The vestibular system is able to detect the direction of one's motions. The somatosensory system, made of muscle and joint receptors, provides information to the brain as to which areas of the body are in motion.

In addition, recent research using the dual task paradigm has provided evidence that attentional resources are used to maintain posture. The dual tasking methodology is a testing model that requires one to engage in two tasks simultaneously, such as balancing and performing a cognitive task. A dual task interference occurs when there is decrement in the performance of one or both tasks. A variety of postural tasks have been employed in combination with a variety of cognitive tasks in researching the dual task paradigm among specific groups of individuals, including healthy individuals, those with vestibular disorders, the young, and the elderly. The majority of research focuses on the importance of a conscious attention in the regulation of postural control. Other research focuses on the effect of postural control on the performance of a cognitive task. The inconsistency in previous research leads to further scrutiny of the dual task paradigm. Most recently, a task-switch paradigm has been used as a way to evaluate executive processes.

Rationale for the Study

The present experiment extends a previous research study that examined non-concussed young adults via a dual-task paradigm (Resch et al., 2008). Nineteen participants were tested over 3 days and performed either a single (balance or cognitive) or dual-task (cognitive and balance) protocol. The balance task consisted of a modified Sensory Organization Test (SOT) on a NeuroCom Smart Balance Master (NC) , which provides six conditions developed for balance assessment: fixed surface and fixed vision (fixed-fixed), fixed surface absent vision (fixed-absent), sway-referenced vision and fixed support (fixed-sway), fixed vision with sway-referenced support (sway-fixed), absent vision and sway referenced surface (sway-absent), and sway referenced vision and sway referenced support (sway-sway). Each of six conditions was presented three times and each trial lasted 60 seconds. The cognitive task consisted of an auditory task which entailed listening and responding to letters as vowels or consonants and numbers as odd or even by clicking a corresponding mouse key. The stimulus category remained constant for a series of trials (e.g. 3 letters) and then was switched to the alternate category (e.g., numbers).

Participants' response times to the last stimulus presented in a series (non-switch RT) and the response times to the first stimulus presented following the category change (switch RT) were compared. The analyses revealed significant differences in balance scores between two of the six conditions. SOT scores were significantly higher under during the dual-task condition 1 (fixed surface and fixed visual reference) and condition 3 (fixed-sway). Response times were significantly longer on switch trials than non-switch trials during both single and dual-task conditions. There was a significant interaction between Trial Type (switch vs. non-switch) and Test Condition (dual vs. single task). RT during dual-task conditions was longer than during single-task conditions, but only on switch trials. Trend analyses revealed a significant linear relation for the Test Condition X Balance interaction, indicating that RT lengthened as the balance demands increased. Analyses of response errors yielded main effects for Trial type, which was qualified by a significant Trial Type X Test Condition interaction. Participants made more errors during dual-task conditions, but only on switch trials.

These results suggest that when balance is perturbed, dual-task costs are observed that are specific to mental processes required to switch attention from one category to another category. Further, increased response errors in the switch task condition were associated with increased postural instability. These findings support the “posture first” principle (Kerr et al,1985), which proposes that postural control is attentionally demanding and resource requirements increase with the complexity of the postural task being performed. (Andersson et al,2002; , Kerr et al, 1985) This hypothesis explains why the increase in balance during the dual task condition occurs at the cost of increased reaction time and error rate. Most likely, this a result of incorporating the vestibular system opposed to solely visual and somatosensory stimuli during a complex cognitive task. (Vuillerme & Nougier, 2004; Vuillerme & Nougier, 2000)

The purpose of Resch et al.’s (2008) study was to explore the possibilities of employing the dual-tasking technique in the concussed population. An inherent limitation of the study was the population consisted of healthy young adults. Given the relationship between increased perturbations in balance, increased reaction time and errors, one would assume these effects would be exaggerated in a concussed population, where the vestibular system may function inefficiently. Few studies have utilized the dual-tasking paradigm with participants whose vestibular system is disturbed.

Purpose of the Study

The purpose of the study was to extend the research performed by Resch et al. (2008) by investigating the impact of balance disruption induced by wearing a weighted backpack on the cognitive functions of volunteers recruited from the UGA Army and Air Force ROTC. This methodology addresses selective effects of environmental demands on military personnel's' situational awareness.

Hypothesis

1. A 30 % body weight load will disturb participants' balance performance.
2. Cognitive function will be impaired more under a 30 % body weight load condition than under a no-load condition.
3. The magnitude of disruption of cognitive function will be related directly to increases of balance perturbation.

Definitions

1. ALICE pack- All-Purpose Lightweight Individual Carrying Equipment that consist of a pack supported on the soldier's back by a metal frame with shoulder straps and a belt with suspenders for carrying items which must be readily accessible.
2. Carriage Load- weight carried in an ALICE pack by military personnel.
3. Dual-Task Paradigm- the theory that the brain's information processing capacity is limited. The performance of any task requires some portion of the attention. The sum of the attentional requirements of performing two tasks separately is equal to that of performing the two tasks simultaneously. A dual task inference occurs when the two concurrent tasks exceed the available attentional capacity.

4. Military Personnel- University of Georgia Army and Air Force Reserve Officers' Training Corps members.
5. NeuroCom Sensory Organization Test- consists of six conditions developed for balance assessment: fixed surface and fixed vision (fixed-fixed), fixed surface absent vision (fixed-absent), sway-referenced vision and fixed support (fixed-sway), fixed vision with sway-referenced support (sway-fixed), absent vision and sway referenced surface (sway-absent), and sway referenced vision and sway referenced support (sway-sway).
6. Non-Switch Task- the repetition of the same task in the task-switch paradigm.
7. Situational Awareness- being aware of what is happening around you to understand how information, events, and your own actions will impact your goals and objectives, both now and in the near future
8. Switch-Task- switching between two tasks in the task-switch paradigm.
9. Task-Switch Paradigm- the theory that examines the performance of different tasks that alternate. Since the tasks are different, some transformation has to take place that changes the cognitive systems' readiness to perform one task into a readiness to perform the other task.

Chapter 2

REVIEW OF RELATED LITERATURE

Attentional processes have long been of interest to psychologist and motor behavior researchers and numerous theories have been proposed to explain the phenomenon (Schmidt & Lee, 2005). Theories of attention fall into two broad categories: selective attention theories and capacity model theories. Selective attention theories suggest attention has a fixed capacity and is a single resource that can only be directed at one operation at a time (Schmidt & Lee, 2005). Selective attention can be either intentional or incidental. The capacity model theories suggest that only one processing task can be attended to at a time (Schmidt & Lee, 2005). If two tasks are performed simultaneously and exceed available attentional capacity, a performance decrement will be seen in one of the two tasks or in the performance of both tasks. The capacity model theory also proposes that if the two tasks can be performed as well simultaneously as they can be performed individually, then one of the two tasks does not require attentional resources. In order to assess attentional resources, the dual-task paradigm, which requires an individual to perform two tasks simultaneously, has been used extensively.

Recent research using the dual task paradigm has provided evidence that attentional resources are used to maintain posture. A variety of postural tasks have been employed in combination with a variety of cognitive tasks in studies that employ the dual task paradigm. The method has been used to assess the performance of healthy individuals, those with vestibular disorders, the young, and the elderly. The majority of research focuses on the importance of a conscious attention in the regulation of postural control. Other research focuses on the effect of postural control on the performance of a cognitive task. For the purposes of our research, postural control and cognitive performance while standing is of most interest.

Literature regarding military personnel and load carriage was also of interest. Research exploring the biomechanics of load carriage in military personnel has provided evidence that postural control and stability is altered as load increases (Beekley, 2002; Quesada et al., 2000) . No studies, however, have addressed the effects of load carriage on attentionally demanding tasks.

Research on the Dual-Task Paradigm: Focus on Postural Control

The interrelations between postural control and cognitive function emerged as an interest after Kerr et al. (1985) showed that postural control draws upon attentional resources and that postural control is susceptible to interference from cognitive activity. Traditionally, the limited resources and capacity theory of attention has been an accepted approach to understanding the dual-task paradigm (Woollacott & Shumway-Cook, 2002). This theory proposes that the brain's information processing capacity is limited. The performance of any task requires some portion of the attention. The sum of the attentional requirements of performing two tasks separately is equal to that of performing the two tasks simultaneously. A dual task inference occurs when the two concurrent tasks exceed the available attentional capacity. Thus, when one needs to maintain their balance while performing a concurrent cognitive task, one's attention is divided among the sensorimotor task and the concurrent cognitive task. The efficiency of postural control under a dual task condition may decrease when compared to postural control under a single task condition, as the sharing of attentional resources between the two functions reduces the amount of attention available for postural control.

Pellecchia (2003) provided evidence in support of the limited resources theory. He examined whether postural sway varied with the difficulty of a concurrent unrelated cognitive task. Participants stood on a foam pad, to create a compliant surface, and were tested under four conditions of varied attentional demand. Information reduction tasks were used to quantify the attentional demands of the cognitive activity. These tasks included: digit reversal, digit classification, and counting backward by 3s. Results showed attentional demands of the cognitive task impacted postural sway, with the most difficult cognitive task having the greatest influence. Main effects of cognitive task condition were found for length of the path of the center of pressure (LPOC), sway range for AP range and ML range, sway variability in the AP direction, and error rates. Post hoc analysis showed LCOP was greater for the counting backwards condition than the other three experimental conditions. Post hoc comparisons showed greater AP and ML range for the counting back by 3s task than for the other three cognitive tasks. AP sway variability was greater when participants counted back by 3s than when performing all other cognitive task conditions. Post hoc testing showed a higher error rate for the counting backward by 3s task than the reversal and classification tasks. These results lead Pellecchia to conclude that cognition and motor performance are related. Pellecchia supports Posner's (1964) suggestion that information reduction reflects task difficulty and provides additional support for the use of information reduction tasks as an effective manipulation of cognitive activity. Pellecchia also suggest conducting further research to determine whether dual task training improves task integration and decreases dual-task interference.

The majority of research, however, fails to support the limited resources and capacity theory of attention. Several studies have found healthy individuals demonstrate enhanced postural control under dual-task conditions. Kerr et al. (1985) investigated the interaction between postural regulation and spatial processing by having 24 college students perform a single hour-long session in which they were blindfolded and performed (a) a memory task alone (while sitting), (b) the Tandem Romberg standing balance task alone, and (c) concurrent memory and balance tasks. Subjects were assigned to either a spatial memory task, which required remembering number-word pairs by mentally placing the numbers in an imagined 4 × 4 matrix, or a nonspatial memory task, which required remembering number-word pairs as paired associates (Brooks, 1967). There were five trials for each of the three conditions that lasted 12 seconds each. The vertical, anterior-posterior, and medial-lateral components of the ground reaction force acting on the feet were recorded continuously by a force platform. Steadiness was better during the memory tasks than during balance-alone conditions for mean absolute distance, standard deviation of absolute distance, mean medial-lateral distance, mean anterior-posterior distance, medial-lateral range, and anterior-posterior range, respectively.

Similarly, Andersson et al. (2002) found that the increased postural control occurred when performing concurrent task. The study consisted of two 2 experiments. The first experiment was designed to assess the effects of a balance task, in which posture was perturbed by stimulation of the calf muscles, on participants’ performance of a silent mental arithmetic task, consisting of counting backwards silently. The second experiment assessed the effect of the mental task on balance functioning. There were four assessment conditions for experiment one: standing on a platform with no calf stimulation; standing on a platform with no calf stimulation and simultaneously counting backwards silently; standing on a platform with calf stimulation to perturb balance; standing on a platform with calf stimulation and simultaneously counting backwards silently. The second experiment was designed to control for the effects of focused attention towards balance. The test conditions were similar to those used in the first experiment, with the additional instruction for the participant to monitor his/her balance and to rate postural perturbation. Twenty three trials, each lasting 20 seconds were conducted while the subjects were tested while standing on the force platform. On half of the trials vibratory stimulation was applied to the gastrocnemius muscles of both legs to evoke body sway. In the first experiment, analyses of the anterior–posterior sway data showed a significant repeated measures effect. Post-hoc t-tests revealed the subjects swayed less when performing the mental task while receiving vibratory calf stimulation compared to the calf stimulation only. Analysis of lateral sway data in the first experiment also showed a repeated measures effect. Subjects swayed less while doing the mental task when not receiving vibratory calf stimulation compared to standing on the platform only. In the second experiment where attention was directed toward balance, analysis of lateral sway resulted in a repeated measures effect indicating that the subjects swayed less while doing the silent counting and stimulation simultaneously, compared with just receiving stimulation.

Broglio, Tomporowski, and Ferrara (2005) evaluated the separate and combined effects of cognitive test performance and balance performance in 20 healthy subjects.

Balance was perturbed in 20 non-concussed young adults via a NeuroCom Smart Balance Master SOT. Participants performed four visual input conditions of the SOT fixed visual reference and fixed surface (fixed-fixed), fixed surface and sway-referenced (fixed-sway), sway-referenced surface and fixed visual reference (sway-fixed), and sway-referenced surface and vision (sway-sway). Subjects completed three trials of every condition for a total of twelve trials. During each 20 second SOT condition, participants performed a visual switch task developed by Kramer et al. (2002), which was designed to isolate mental operations involved in stopping the computation processes required to perform one task and to initiate processes required to perform a different, non-relevant, task. Balance and cognitive-task performances under dual-task conditions were compared to single-task conditions in which participants completed the balance and cognitive tasks independently. Condition balance scores were significantly higher under the dual-task condition during the fixed-fixed, fixed- sway, and sway-fixed conditions. Analysis of the sway-sway condition was not significant. The researchers suggest the improvement in postural control under the dual-task test conditions could be explained in terms of type of processing required of the participants. They also suggested that future studies pertaining to dual tasking and postural control should consider modifying the cognitive task to one that allows for the eyes to be closed during the balance assessment.

In exploration of the effect of different types of cognitive task on posture, Dault, Frank, and Allard (2001) examined varying types and varying levels of difficulty of working memory task on posture. Participants sat in a chair or stood on a force plate in two different postural stances (shoulder width stance and tandem stance) while performing three different working memory tasks: a verbal task, a visuo-spatial task with two levels of difficulty, and a central executive task. When a working memory task was added, changes in postural sway were characterized by an increase in frequency in the AP direction and decrease in amplitude of sway in the AP direction, indicating a tighter control. The difficulty level of the working memory task did not produce changes in postural control. Thus regardless of task type or task difficulty, the researchers suggest, the CNS chooses a co-contraction control strategy, which provides a tighter control of postural sway when simultaneously performing a working memory task.

Other studies have also examined postural sway as it relates to the difficulty of a task. Riley, Baker, and Schmitt (2003) examined the effects of concurrent short-term memory demands on postural control. Postural stability of 23 participants was measured while each stood on a balance platform or stood on a balance platform while performing a digit rehearsal task of varying levels of difficulty. Participants were briefly presented with a random digit string before postural sway data collection began. The digits were removed, and participants mentally rehearsed the digit string while maintaining posture. Immediately after the postural data collection period ended, participants reported as many of the digits they could remember. The cognitive task difficulty was specified to each participant's short-term memory capacity by measuring each participant's maximum digit span prior to postural testing. A significant main effect was found for digit-span difficulty for the standard deviation of AP sway and post hoc tests revealed significantly less sway variability in the medium and difficult conditions than in the easy condition. The researchers rejected attention theories that assume a limited cognitive capacity or pool of cognitive resources because they cannot account for improved balance performance under dual-task conditions. They do, however, give recognition to an arousal theory, which suggest arousal, in some sense, recruits cognitive resources (Kerr et al., 1985), which when in a dual task condition could lead to improved balance performance.

To further examine the relationship between postural sway and short term memory task, Riley et al. (2005) performed a systematic replication of their previous experiment (2003). In Experiment 1, the Riley et al. (2003) study was replicated by using a broader range of balance conditions, which included a fixed balance platform and a foam covered balance platform. In Experiment 2, an auditory version of the short-term memory task used by Riley et al. (2003) was introduced, in which digits were presented auditorily. In Experiment 1, sway was less recurrent and there were two effects of the digit task on postural sway: SDL-ML decreased with increasing cognitive load, and AP sway complexity decreased with increasing cognitive load. A post hoc test revealed that AP entropy was significantly lower in the difficult task condition than in the no-task condition. The postural stability results in Experiment 2 were consistent with those in Experiment 1. Increasing the difficulty of the auditory short term memory task was associated with a decline in SDL-ML. The researchers acknowledge that a decrease in COP SD is usually interpreted as an increase in postural stability; however they suggest their results are open to an alternative interpretation associated with a degrees of freedom strategy adopted by the postural control system when directed cognitive activity draws away attention that may actually interfere with, rather than facilitate, postural control.

Research on the Dual Task Paradigm: Focus on Cognitive Assessment

In addition to examining the postural elements the dual task, examining the cognitive components also are critical to understanding the dual task paradigm and developing theories based on the results. Researchers typically report a decrease in cognitive functioning when asked to perform a dual task, depending on the task at hand. Kerr et al. (1985) examined a spatial and non-spatial task and found that the concurrent balance requirement led to a decrement in recall scores for the spatial task but not the non-spatial task. Riley, Baker, and Schmitt (2003) found that the difficulty of the condition was significantly related to the accuracy of the recall task used. A total of 2 errors were committed in the easy condition, 7 in the medium condition and 17 in the difficult condition. Andersson et al.'s (2002) two part study demonstrated a dual-task effect was found in for the first portion of the experiment, with lower scores obtained when the balance was challenged; however, this effect was not observed in the second portion of the experiment. The only differences between the portions were that in the second portion attention towards balance and the vibratory stimuli was controlled by means of letting the subjects perform a rating task silently while standing on the platform. The researchers were unable to identify an explanation for the differences between the two studies. As with Andersson et al.'s (2002) second portion of his study, other researchers have failed to find significant decrements in the performance of the cognitive task when a postural was perturbed (Broglio, Tomporowski, & Ferrara , 2005).

A 'posture first' principle has been suggested to explain the decline in performance of the cognitive task under the dual task condition (Hunter and Hoffman, 2001). This principle suggests that difficult balance task result in more cognitive interference and balance is prioritized. The 'posture first' principle is also associated with studies that have shown subjects to stiffen their posture under the dual task condition, thus decreasing the amount of sway (Ehrenfried et al., 2003; McNevin & Wulf, 2002; Winter et. al, 1998). Riley, Baker, and Schmitt (2003) propose that the amount of attention usually directed to postural control usually has a detrimental effect; however, when one focuses their attention to another task, postural control work in a more automatic, efficient manner to reduce sway. Furthering their research Riley et al. (2005) proposed that directed cognitive activity draws away attention that may interfere with postural control. Imposing a high cognitive load may result in participants adopting a degrees of freedom freezing strategy, where they freeze the cognitive load controlling posture and free cognitive resources to support the memory task. By freezing the degrees of freedom, one becomes more rigid in their posture but is more susceptible to perturbations.

An action selection theory also provides an approach for understanding the dual task paradigm. This theory, also supported strongly by Neuman (1987), suggests that two task performed at the same time are not independent, but that the motor system integrates concurrently performed activities by means of action planning and coordination between two task is acquired with practice. Pellecchia (2005) examined the action selection theory using dual-task training and hypothesized a concurrent cognitive task would not amplify postural sway after training. Participants were assigned to one of three treatment groups: no training, single-task training, or dual-task training. During training, participants stood on a force plate, which measured balance and postural sway, and looked at the plastic disc mounted on the wall that faced them. For the dual-task condition, participants performed the standing postural task concurrently with a cognitive task that consisted of counting backward by threes from a randomly chosen three-digit number. Participants assigned to single-task training group and dual-task training groups underwent three individual training sessions. Postural sway was measured during three 30-s trials of quiet standing and three 30-s trials of concurrent postural and cognitive tasks. Participants in all three groups returned 1 week following the pretesting session to undergo posttesting, which proceeded in the same manner as pretesting. The ANOVA for pre-test revealed there were no initial differences between the three training groups. The balance scores revealed that dual-task training, but not single-task training, eliminated dual-task interference in the posttest. Posttest error rates for the cognitive task did not differ from pretest error rates for the three training groups. The researcher suggested that dual-task skill is best acquired through dual-task practice that provides opportunity to coordinate and integrate component tasks.

Research on the Dual-Task Paradigm with Special Populations

Individual differences in attentional capacity may also explain inconsistencies in dual task research. The dual-task paradigm has employed to test children, those with concussions, those with other vestibular disorders, and most notably the elderly. Few studies have addressed the dual task paradigm as it relates the assessment of pediatric balance. Inferring relations between cognitive processes and postural control is a relatively topical challenge in developmental neurology (Schmid, 2007). Schmid (2007) investigated the effect of a concurrent cognitive task on postural control in a sample of 50 nine-year-old children. The results obtained suggest that at approximately nine years of age a maturation of balance control emerges, and children have already developed the effective use of a head stabilization strategy. In an attempt to determine whether the selective and coordinated control of the degrees of freedom is already present, the researchers employed a concurrent cognitive load to see how it affects balance control in this specific age group. Each subject completed two 60-second balance trials. One balance trial was performed with a concurrent cognitive task, consisting of counting backwards by 2's from 20. The other balance trial was performed with no cognitive load. Twelve posturographic parameters were extracted from the centre of pressure trajectory obtained through a load cell force plate. The children also underwent a Physical Examination for Neurological Subtle Signs (PANESS) and Teacher's Rating. These two procedures are identified as predictors of cognitive function. Significant differences were found in the 75% of the extracted posturographic parameters. COP was found to faster mean velocity, a larger mean amplitude and sway area, and with substantially different features demonstrating an overall broadening of the spectrum in the frequency domain. Also, participants that scored lower on the motor task portion of the PANESS showed poorer performance on the postural task. The researchers concluded that the results strengthen the assumption that concurrent cognitive task strongly affects postural strategies in children.

With the incidence of concussions on the rise, postural stability assessments have become more popular for evaluating the severity of a concussion and help clinicians establish when normal activity can resume safely, especially as it pertains to athletes. Recently, the dual-task testing method has been introduced as a sensitive measure of the effects of concussion on neurocognitive function. The physical and mental demands experienced by the participant are designed to be similar to those athletes encounter in sport. Broglio et al. (2005) evaluated the interrelation between balance perturbation and a visual test designed to assess executive function (i.e. planned goal-directed behavior). As reviewed in the Section 1, the results suggest that increased balance perturbation lengthens the time required to identify and respond to stimuli. However, balance perturbation did not influence switch cost, which are used as an index of the efficiency of executive processing. (Broglio et al., 2005)

Several neuropsychological tests have been developed to assess cognitive performance; however, there is a paucity of information on gait and dynamic stability for young concussed adults. Parker et al. (2005) investigated the effect of divided attention in 20 participants with Grade 2 concussions and 10 nonconcussed participants on various gait variables in a matched pairs study. The gait protocol consisted of level walking with no obstructions and was performed by each subject under two conditions: with undivided attention and while simultaneously completing simple mental tasks. The mental tasks consisted of spelling 5-letter words in reverse, subtraction by sevens, and reciting the months of the year in reverse order. Whole-body motion data were collected using a six-camera motion analysis system. A 13-segment biomechanical model was used to compute whole body center of mass motion and velocity. The researchers found that during the dual-task condition both groups displayed a gait pattern with a significantly slower gait velocity, shorter stride length, and longer stride time than during the single-task condition. The concussion group adopted a significantly shorter stride length and demonstrated a slower, but not significant, gait velocity than the matched controls. There were no significant group or task effects for step width. Concussed subjects were found to be able to adjust their whole body center of mass motion to maintain dynamic stability while walking without divided attention; however, while walking with divided attention, concussed subjects demonstrated 42% more medio-lateral center of mass sway. The researchers suggest the dual-task condition possibly required more than the attentional capacity available and, as a result, gait stability was compromised. The control group also showed dual-task interference, marked by decrease in gait performance during the dual-task, but the concussion group was affected to a greater degree.

Yardley (2001) investigated whether interference between postural control and mental task performance in patients with vestibular disorders is due to general capacity limitations, motor control interference, competition for spatial processing resources, or a mixture of these factors. Participants were patients with vestibular disorder and healthy controls. Patients with peripheral vestibular disorder have intact attentional processing but often exhibit increased postural instability. Moreover, dizzy patients often complain of difficulty concentrating, clumsiness, and fatigue16- symptoms which could indicate mental exhaustion or overload (Yardley et. al, 2000). The study assessed a total of 48 patients with peripheral vestibular disorder and 24 healthy control participants. Postural stability was assessed under two conditions: standing with eyes closed on a stable platform and standing with eyes closed on a destabilized, sway referenced platform. The mental tasks were designed to permit comparison of low load tasks with high load tasks, as well spatial tasks with non-spatial tasks. A total of 28 trials were conducted. Participants with vestibular disorders had significantly lower equilibrium scores than controls both when standing on the stable platform and on the destabilized platform. The results of the study revealed that competition for spatial processing resources was not likely the reason for dual task interference, as levels of interference were similar in patients with vestibular disorder and healthy controls, and were also similar for spatial and nonspatial tasks. While accuracy declined on the high load tasks when balancing, the researchers conclude this could not be attributed to motor control interference as no motor control processing is involved in maintaining accuracy of responses. The researchers rejected the notion of general capacity limitations, and suggested that a decrement in dual task performance was proportional to the attentional demands of both tasks.

An inability to produce an appropriate postural response due to the competition for attentional resources between the postural system and the cognitive task has been suggested to contribute to falls in elders with poor balance (Shumway-Cook et al., 1997). The elderly show a decline in postural stability when presented with a concurrent task, as well as a reduction in the performance of the cognitive task in most cases, specifically, an increase in reaction time. Clarification as to the possible mechanism by which declining postural control requires increased attentional resources while performing a concurrent task has received little attention. Most research has focused on the mechanisms of posture that decline with age, as well as causes of postural deficits that lead to falls in elders.

Shumway-Cook et al. (1997) used a dual task method to examine the changes in attention associated with the performance of concurrent secondary cognitive tasks and how they affect postural stability more in 20 elders with a history of falls, compared to 20 healthy young and 20 elders. Initially, four clinical tests were chosen to evaluate functional balance and walking skills: The Berg Balance Scale, The Three-Minute Walk Test, The Performance Oriented Mobility Test, and The Dynamic Gait Index. Two secondary cognitive tasks, Sentence Completion and Judgment of Line Orientation (JOLO), were used to produce changes in attention during the performance of a concurrent postural task during quiet stance under flat vs. compliant surface conditions. Postural stability was measured using a NeuroCom balance Master in the six conditions: firm surface/no task, firm surface/JOLO task, firm surface/sentence task, compliant surface/no task, compliant surface/JOLO task, compliant surface/sentence task. Shumway-Cook et al. found that stability did not significantly differ between the young adults and the healthy elders. Neither of these groups had significant differences in stability between the no-task and JOLO conditions, but did sway was significantly greater during the Sentences task. In contrast, in the elders with a history of falls, both JOLO and Sentence Completion significantly increased sway over the no-task condition. These results suggest that when postural stability is impaired, even relatively simple cognitive tasks can further impact balance; however, increasing the difficulty of the postural tasks did not significantly impact performance on the cognitive tasks. The researchers support the notion that the allocation of attention during the performance of concurrent tasks is complex; depending on many factors including the nature of both the cognitive and postural task, the goal of the subject, and the instructions.

The differences in allocation of attentional resources between type of balance tasks has been assessed, with static tasks appearing to require less attention than dynamic tasks. Marsh and Geel (2000) assessed the attentional demands of postural control during quiet standing using a dual-task paradigm in 14 young and 16 older women. Participants first performed a verbal reaction time task while sitting. Next, participants were instructed to focus on maintaining a quiet standing posture on a force plate and to verbally respond to the auditory stimulus as quickly as possible during the following balance conditions: eyes open/hard surface, eyes closed/hard surface, eyes open/foam surface, eyes closed/foam surface. Older women required more cognitive resources to maintain simple eyes open standing posture compared to an eyes open seated posture compared to younger women. Also, older women had significantly greater verbal reaction times during the dual-task compared with younger women. For both the groups, verbal reaction times did not significantly change as the difficulty of the balance task increased. The researchers concluded that elders may be at risk for falls in situations where they may be engaged in concurrent tasks, even when those tasks are considered automated and/or lower order operations.

Researchers have also explored the extent to which cognitive task difficulty alters elders’ balance control. Maylor and Wing (1996) assessed whether or not elder participants would show greater interference than younger participants when the postural and cognitive tasks were performed together over a range of cognitive tasks. Thirty eight participants over 50 years of age took part in the matched pairs study. Two groups were formed based on prior testing (mean ages of 57 and 77). Participants were required to either sit (single task) or stand (dual task) on a force platform while performing five cognitive tasks: random digit generation, Brooks' spatial memory, backward digit recall, silently counting from 1-100, and counting backward in threes. There was also a control condition in which there was no cognitive task. The researchers found postural stability was adversely affected by age in all conditions. The difference between the two age groups was significantly greater when performing tasks Brooks spatial memory task and backward digit recall, in comparison with the age difference in the control condition. The researchers suggested that the pattern of age differences in postural stability is increased by cognitive tasks using the visuo-spatial sketchpad component of working memory, which is play a role in setting up and manipulating visuo-spatial images.

Jamet et al. (2007) explained the deterioration of postural performance in the elders in terms of a decreased ability to allocate the resources needed to fulfill the secondary task, which belong to a field in competition with the postural task. The consequence of the competition is deterioration of their postural performance. Weeks et al. (2003) found this only to be true when there was a motor task present. In their study, both cognitive and motor focal task performances, as well as center of pressure (COP) excursion, were examined in healthy elderly and young subjects. The cognitive task involved solving a multi-step arithmetic problem, and the motor task involved a continuous static finger-thumb pinch task at a target force. COP during quiet stance was recorded for 30-second trials with a force platform while participants performed a no-focal task pretest, cognitive focal task only, motor focal task only, cognitive and motor focal tasks simultaneously, and no-focal task posttest. Results show performance of focal task was not influenced by increasing postural demands. COP excursion only increased over the quiet standing pretest condition when performing the motor focal task (13% difference in the M-L plane). This suggests a reduced ability to suppress sway when the motor system was concurrently occupied with a voluntary task that shared the same input-output resources. Weeks et al. (2003) also support that of Meltzer et al.'s (2001) research, which suggest a co-contraction strategy becomes active so postural regulation would then require less attentional capacity, as the ability to share attentional resources among focal and postural tasks was similar in healthy young and elderly subjects.

In addition to static balance test, the same dual task interference has been found in the elderly when gait patterns were analyzed (Beauchet et al., 2003; O'Shea, Morris, & Iansek, 2002). Researchers have found the elderly decrease their walking speed as a strategy to avoid loss of balance. Gait performance also becomes much more variable and random as different cognitive task are presented to elders.

Research on the Task-Switch Paradigm

The task-switch paradigm has been used extensively as a measure of executive control. In task-switching experiments, participants are asked to perform different tasks that alternate. Since the tasks are different, some transformation has to take place that changes the cognitive systems' readiness to perform one task into a readiness to perform the other task. Discovering how the transition is accomplished remains the objective of task-switching research.

Jersild (1927) showed that under some conditions switching between two simple tasks takes more time than the repetition of the same task. The required to switch from one task to another task is described as the switch cost. Several researchers suggest that switch costs reflect the time the cognitive systems needs to reconfigure itself to the changed task demands, reflecting an active process of goal shifting (Goschke, 2000; Meiran, 1996; Monsell, Yeung, & Azuma, 2000; Rogers & Monsell, 1995; Rubinstein, Meyer, & Evans, 2001). Other researchers suggest that task repetitions are answered faster and more accurately because of to a carryover effect from the persistent execution of the same task (Allport & Wylie, 2000, Altmann, 2004a, 2004b; Dreisbach, Haider & Kluwe, 2002; Dreisbach & Haider, 2005; Koch, 2001, 2003; Logan & Bundesen, 2003; Ruthruff, Remington & Johnston, 2001; Sohn & Anderson, 2001; Sohn & Carlson, 2000; Wylie & Allport, 2000). This research does not deny the involvement of cognitive control processing in task switching; however it suggest that switch costs do not reflect a measure of cognitive control.

The switch cost effect has led to two major competing hypotheses regarding the nature of executive control processes. The task set inertia hypothesis (Allport et al., 1994) accounts the switch cost to the persisting activation of the task that was relevant prior to the switch. When subjects switched from Task A to Task B, the activation in the processing pathway associated with Task A remained high until sometime after the switch to Task B. The persisting activation of Task A interfered with the processing required for Task B. The switch cost was a consequence of interference from the previous task to fully prepare for the new task. An alternate hypothesis was the task set reconfiguration hypothesis (Monsell, 1996) in which the ability to do some effective preparation prior to a switch of task was a specific component (Rogers & Monsell, 1995; Monsell, 1996). This hypothesis proposed two stages: the first is under subjects' voluntary control and can precede the arrival of the new stimulus; the second is not under voluntary control, and was only initiated when the new stimulus was actually presented. The second stage is similar to that of the task set inertia hypothesis.

Research on Load Carriage and Posture in Military Personnel

The majority of literature pertaining to military personnel involves the biomechanical, physiological, and psychological effects of load carriage and different backpack designs and load carriage systems. The research related to load carriage requirements in the field has increased in recent years because of the need to carry more equipment for increased protection or firepower (Beekley, 2007). These studies usually incorporate long road marches and/or a variety of training factors. Various loads are used throughout studies to evaluate at what load amount military personnel begin to have the most significant decrements in their performance.

Quesada et al. (2000) examined the effects of lighter load carriage in twelve Army Reserve Officer Training Corps (ROTC) cadets. Performance of three, 40-min treadmill marches at 6 km/h, with each of three load carriage conditions: 0%-BW, 15%-BW load using the Army's ALICE backpack system, and 30%-BW load in the ALICE backpack, were examined. Pelvic and lower extremity motion and ground reaction force data were acquired before and after simulated marching trials. Motion data were obtained with a 6-camera motion analysis system and ground reaction data were recorded by force plates. Metabolic data, oxygen uptake (VO_2), expired ventilation (VE), respiratory exchange ratio (RER), heart rate (HR) and ratings of perceived exertion (RPE) were collected continuously while on the treadmill. Significant differences were observed between each load for VO_2, HR and VE. RPE during marching at 0%-BW and 15%-BW loads were similar while RPE responses during the 30%-BW load were significantly greater than the 0%-BW and 15%-BW loads. Among the loaded-unloaded residuals for kinematic variables, significant differences in residuals for peak knee flexion during stance were by load magnitude, and were greater for 30%-BW load than for 15%-BW load. The researchers suggest marching with 30%-BW will alter the pre-march loading pattern, possibly because of muscle fatigue, estimating fatigue can be based upon metabolic variables.

Beekley et al. (2007) further investigated the metabolic and motivational effects of heavy load carriage. The researchers examined ten male U.S. Military Academy officers’ responses to heavier loads of 30%, 50%, and 70% of lean body mass. Subjects wore an all-purpose, lightweight, individual, carrying equipment (ALICE) backpack, filled to the appropriate weight for each subject and trial with sandbags, for 30 minutes, at a speed of 6 km/h. Oxygen consumption (VO), ventilation, heart rate (HR), respiratory exchange, rating of perceived exertion (RPE), and Self-Motivation Inventory scores for 3 separate stimulated road march trials were collected. The researchers found systematic increases in VO2, HR, and VE with increased loads at the same velocity of road marching. The 50% LBM load was not perceived as being harder work than the 30% LBM load; however, the metabolic cost was greater. It was concluded that HR and relative energy cost are fairly linear between 0% LBM load and 70% LBM load. The researchers also note that the sandbags in an ALICE backpack might have played a role in their results because they tended to migrate to the lowest central area of the pack, which might have driven up energy costs and possibly induced fatigue earlier in their subjects. They suggested researchers should carefully consider placement and type of load in further research using backpack load carriage. The literature pertaining to military personnel has not incorporated the dual task paradigm to assess the interactive relation between environmental demands and load carriage.

Chapter 3

METHODS

Participants

The research study included a volunteer sample of 20 participants (16 males, 4 females) ranging from 18-22 years of age. Descriptive statistics regarding participant characteristics can be found in Table 1. Participants were recruited from the University of Georgia Air Force ROTC and Army ROTC. Exclusion criteria included having been diagnosed with a concussion; speaking a language other than English as their first language; having recent surgery and/or injury of the ankles, knees, hips, feet, and related musculature; and having any known conditions of the inner ear or vestibular system. In order to participate in the study, participants were screened with series of questions related to the exclusion criteria. These questions all required a negative response. 1)"Have you ever been diagnosed with a concussion?" 2) "Is English your first language?" 3) "Are you currently being treated for lower extremity injury?" 4) "Are you currently being treated for inner ear/vestibular infection?"

Instrumentation

Participation included a visit to the Cognition and Skill Acquisition Laboratory for weight measures and preliminary orientation of the testing procedures. Each participant read and signed an institutional review-board approved consent and completed a brief questionnaire of self-reported demographics. Testing consisted of three sessions separated by 24-48 hours and included a balance test and a cognitive task.

The balance test was conducted with the NeuroCom Smart Balance Master (NC) in concert with the Data Acquisition Toolkit (DATa) version 2.0 software (NeuroCom International, Inc., Clackamas, OR) Testing consisted of a modified Sensory Organization Test which consists of six conditions developed for balance assessment (Figure 1): fixed surface and fixed vision (fixed-fixed), fixed surface absent vision (fixed-absent), sway-referenced vision and fixed support (fixed-sway), fixed vision with sway-referenced support (sway-fixed), absent vision and sway referenced surface (sway-absent), and sway referenced vision and sway referenced support (sway-sway). Sway gain was set at 1.0, matching sway referencing to the participant's sway as described in the NeuroCom System Operator's Manual (2001). Each participant completed each of the six conditions three times for a total of 18 separate trials. Each trial lasted one minute and subjects were given a fifteen second break between trials for stretching prior to starting the next trial. The 18 trials were randomized to minimize any practice effect.

The cognitive task was an auditory switch test that involved the presentation of 40 computer-generated letters or numbers to a headphone via a commercial software program (SuperLab 2.01; Cedrus). The letters consisted of 5 vowels (A, E, I, O, and U) and 5 randomly selected consonants (B, D, L, C, and J). The numbers consisted of 4 even numbers (2, 4, 6, and 8) and 4 odd numbers (1, 3, 5, and 7). The participant responded to each stimulus by pressing a key on a serial mouse (Even number - left key; Odd number - right key; Vowel letter - left key; Consonant letter - right key). Each key press was followed 100 ms later by the presentation of the next stimulus. Letters or numbers were presented in series lengths of 1, 2, or 3 stimuli. The letter-number category discrimination switched following each series. The initial 4 trials of each test were considered practice and not evaluated. The remaining 36 trials consisted of 24 non-switch trials (i.e., repetitive within-category discriminations) and 12 switch trials (i.e., a change in category discrimination), with an equal number of switches to even-odd and vowel-consonant conditions. Response times and response accuracy were recorded for each trial. The test terminated with a computer-generated command to stop. Thirty-six unique tests were developed in which the order of blocks of non-switch and switch trials was randomized.

Testing Procedure

During session 1, each participant was familiarized to the balance protocol and the cognitive task. The participant was trained to perform the auditory switch task in 5 phases. Initially, the task was described to the participant, who stood next to a computer station. Next, the participant donned a set of headphones and was instructed to hold the mouse in his/her right hand with both arms at their sides. Participants were then asked to monitor a series of 15 letters and numbers stimuli presented every 500 ms and to adjust the loudness of the stimuli to a preferred level via a volume adjustment dial on the headphone cord. Third, participants were instructed to listen to a series of 30 numbers and discriminate between even and odd numbers with the appropriate mouse key press. Fourth, a series of 30 letters were presented and the participant was asked to discriminate between vowel and consonants with the appropriate key press. Finally, the participant was told that both letters and numbers were going to be presented and to respond quickly and accurately as possible. Stimuli consisted of 120 letters or numbers, which were repeated in series lengths of 1, 2, or 3, and then switched from one category to the other.

There were 80 non-switch and 40 switch trials, with an equal number of switches to even-odd and vowel-consonant conditions.

Sessions 2 and 3 consisted of weighing the subject on an electronic scale, reading instructions, and having the procedure explained. After confirming the participant understood the procedure, testing began with a volume-adjustment trial and a 120-trial practice test administered to the participant while standing next to the computer station for the cognitive aspect of the dual-task. The participant was then instructed to step onto the NeuroCom platform and to perform cognitive test while maintaining balance under 6 different test conditions. Each cognitive test began simultaneously, via the researcher counting backwards from 5, and upon hitting 0, the participant and researcher started each separate task. Each participant finished the cognitive test prior to completing the balance trial. Session 2 consisted of one of two scenarios, the first was to perform the balance test and the cognitive task concurrently; the second being the performing the balance test and the cognitive task concurrently while donning medium all-purpose, lightweight, individual, carrying equipment (ALICE) backpack with an external frame containing sandbags equivalent to 30% of the participant's body weight. Participants performed either scenario for session 2 and performed the remaining scenario for session 3.

Research Design

A within-subjects research design was used (Baumgartner and Hensley, 2006). To reduce potential carryover effects, the order of cognitive task trials was randomized for each individual and the order of sessions 2 and 3 were randomized.

Data Analysis

Condition balance scores, sub-scores, and composite scores were calculated for each trial as described in the NeuroCom System Operator's Manual (2001).

Cognitive test performance was assessed by evaluating participant's response time (RT) and response accuracy to stimuli on trials immediately prior to (non-switch trials) and immediately following a category switch (switch trials). Participants' RT, proportion of response errors, and balance scores were averaged over three successive tests performed under the no-load condition and three tests performed under the load condition for each of the 6 NeuroCom conditions. Separate three-way ANOVA's were used to test the effect of trial type (switch, non-switch), test condition (no load, load), and balance conditions (6 NeuroCom conditions) for RT, proportion of errors, and condition balance scores. All data were analyzed utilizing SPSS (Chicago, IL) version 15.0.

Table 1. Subject Demographics

Sex	(N)	Age (yrs)	Height (in)	Weight (lbs)	Load Weight (lbs)
Male	16	20.31±1.4	70.19±2.9	174.44±25.71	52.25±7.63
Female	4	19.5±1.29	67.75±3.86	167.75±22.47	50.75±6.7

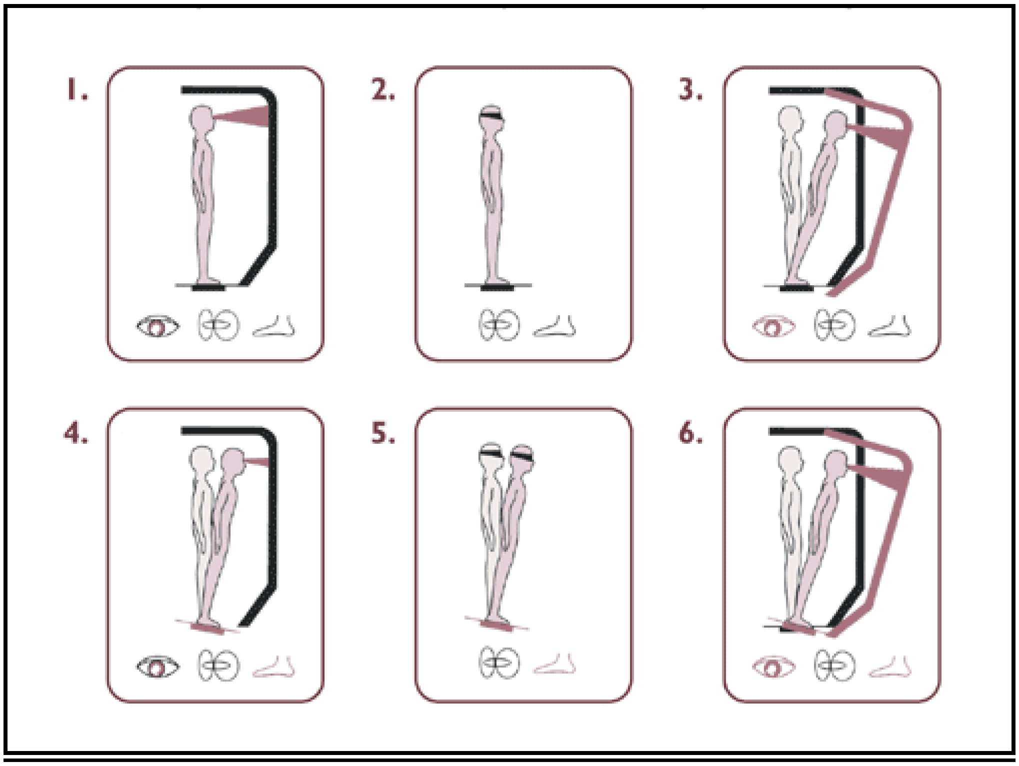

Figure 1. NeuroCom SOT Conditions

Chapter 4

RESULTS

Balance Scores

The ANOVA conducted on balance scores revealed a main effect for both load type, $F_{(1,19)} = 23.05$, $p <.05$, $\eta^2 =.55$, and balance condition $F_{(5,95)} = 177.44$, $p <.05$, $\eta^2 =.90$. As seen in Figure 2, scores were lower when the load was present compared to when no load was present (mean= 67.62 ± 1.32 and 72.5 ± 1.27, respectively). Post hoc analysis revealed that there were significant differences between condition EO and all other balance conditions and between condition EO/SS and all other balance conditions. There were no significant differences between conditions EC and SV and between conditions EC/SS and SV/SS. None of the NeuroCom conditions were influenced differentially by the presentation of load.

Response Time Scores

The ANOVA did not reveal main effects for task type (switch vs. non-switch), load type (load vs. no load), nor between balance conditions. Further, the analysis did not reveal any interactions among the three factors. As seen in Figure 3, participants' RT performance differed as a function of load type and the 6 balance conditions for the switch task; however, the magnitude of the differences was not significant. As seen in Figure 4, the same effect was not seen for the non-switch task.

Proportion of Error Scores

The ANOVA conducted on the proportion of participants' errors scores revealed main effects for load type (load vs. no load) (mean=.024 ± .001 and .016 ± .02, respectively) $F_{(1,19)} = 4.41$, $p = <.05$, $\eta^2 =.19$, and task type (switch vs. non-switch) (mean=.024 ± .002 and .016 ± .001, respectively) $F_{(1,19)} = 17.99$, $p = <.001$, $\eta^2 =.49$. As seen in Figure 4, an interaction between load type and task type was identified, $F_{(1,19)} = 4.43$, $p = <.05$, $\eta^2 =.19$, and it was determined via post hoc analyses that more errors were made when the load was present, but only during non-switch trials.

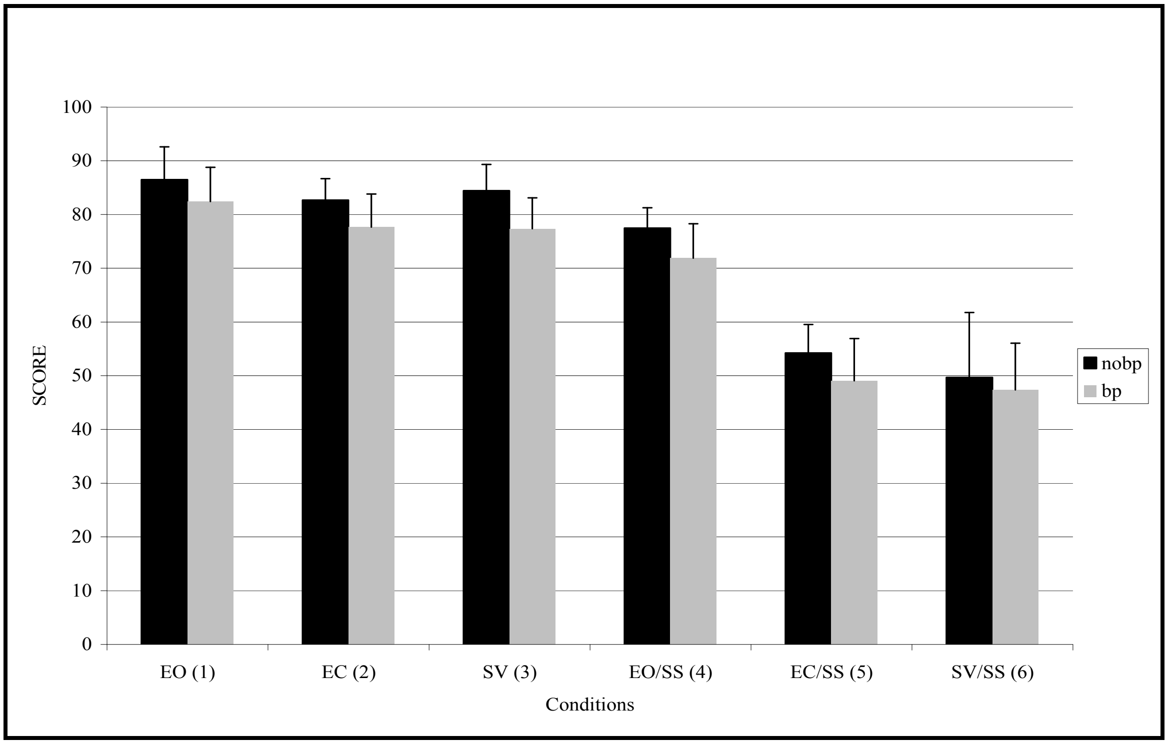

Figure 2. Balance Scores

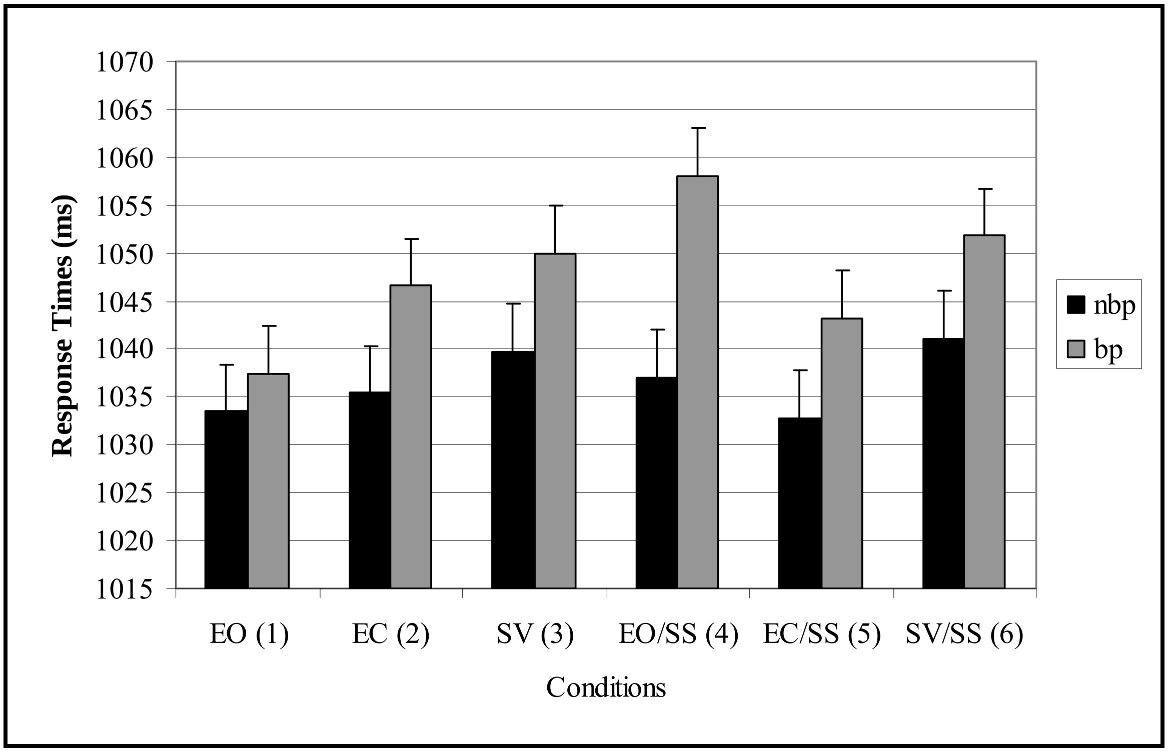

Figure 3. Response Times for Switch Task

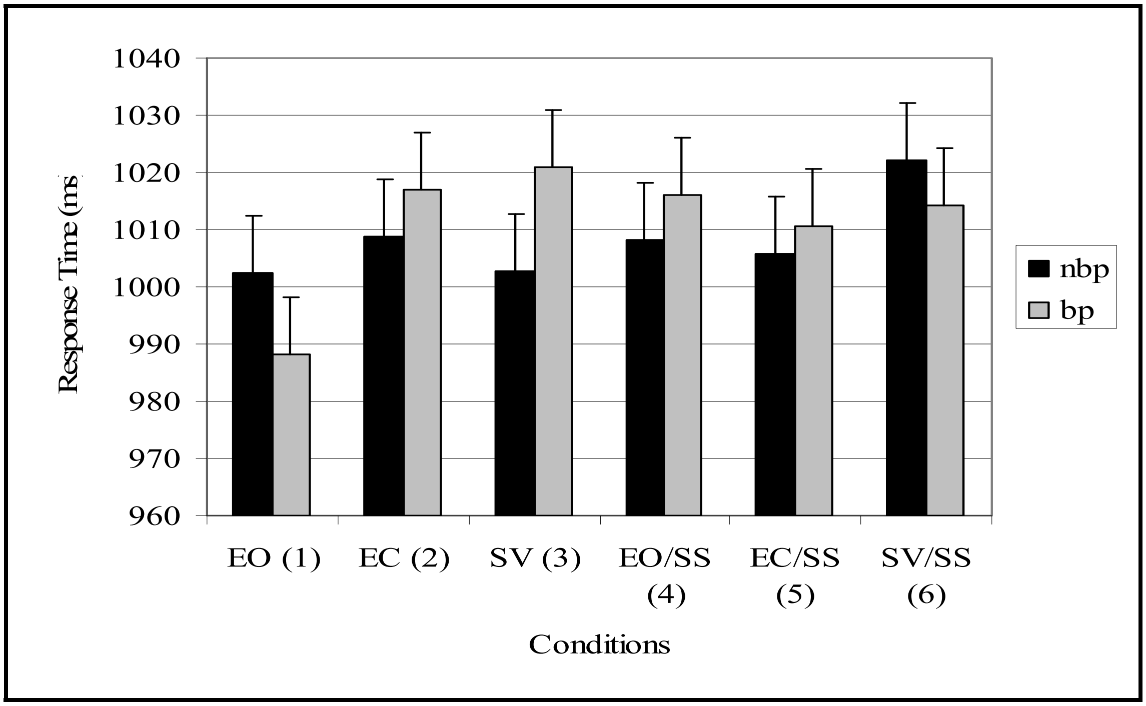

Figure 4. Response Times for Non-Switch Task

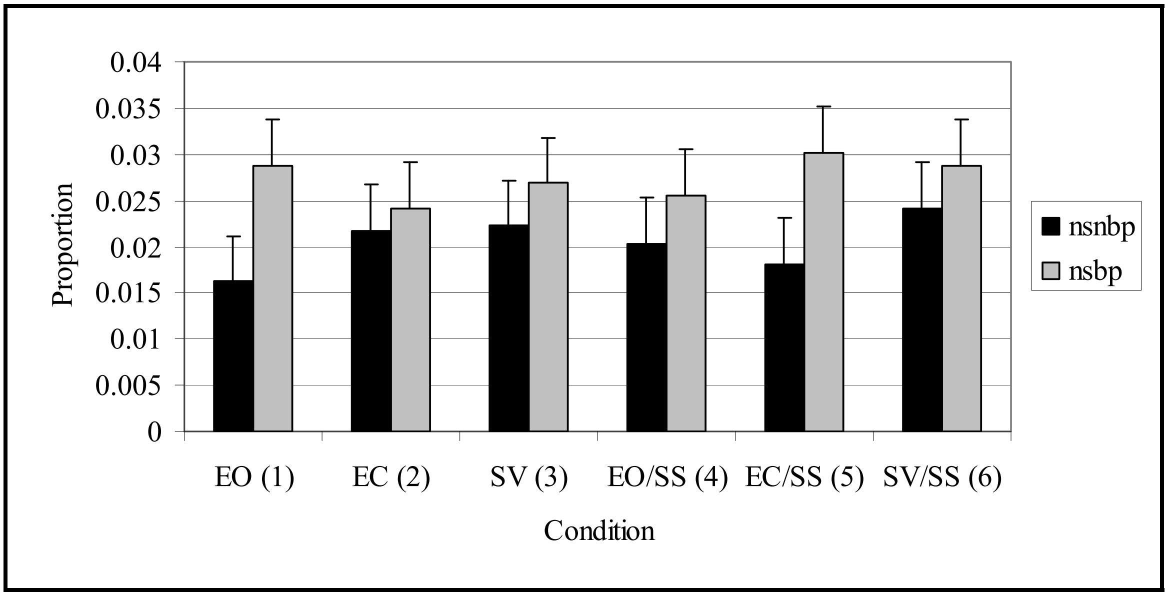

Figure 5. Error Proportions

Chapter 5

DISCUSSION

This project was designed to assess the effects of environmental demands on military personnel's situational awareness. The impact of balance perturbations on information processing of military personnel was assessed via a dual-task method. As expected, the manipulation of carriage load altered participants' balance. The increased carriage load and subsequent demand on maintaining balance was predicted to produce dual task interference. Visual inspection of participants' response speed suggest task interference; however, statistical analyses failed to support the presence of dual-task interference on the decision-making speed of military personnel. The load-induced postural instability did, however, result in more response-choice errors. The frequency of choice errors was greater under non-switch task conditions than switch-task conditions. These findings suggest that balance disruption leads to a speed-accuracy tradeoff in which participants maintain response speed but at the cost of increased choice errors, regardless of experience with additional load carriage. The Army ROTC members had more experience with load carriage systems in training than the Air Force ROTC members, which may have presented a limitation in the study; however, their scores did not significantly differ.

Analyses of balance scores revealed the 30% weight load disrupted the participants' ability to maintain balance across all six NeuroCom testing conditions, compared to when no load was present. Previous research conducted with military personnel suggest that a load consisting of 30% of one's body weight is sufficient to alter biomechanical factors, components of metabolism, fatigue, and have motivational effects (Quesada et al., 2000; Beekley et al., 2007). Our data suggest the 30% weight load also alters postural control. One's ability to balance is determined by the interaction of the postural control system composed of several sensory systems that are hierarchically ordered, including the visual, vestibular, and somatosensory systems. Postural control also involves organizing the components of the balance system into sensory strategies by giving certain weight to each sense. The sensory strategies can vary as a function of age, task, and environment.

The balance test conducted with the NeuroCom consisted of a modified Sensory Organization Test of six conditions developed for balance assessment: fixed surface and fixed vision (fixed-fixed), fixed surface absent vision (fixed-absent), sway-referenced vision and fixed support (fixed-sway), fixed vision with sway-referenced support (sway-fixed), absent vision and sway referenced surface (sway-absent), and sway referenced vision and sway referenced support (sway-sway). The sway-fixed, sway-absent, and sway-sway conditions are generally considered more difficult to perform because they are more dynamic in nature. The sway-fixed condition presents inaccurate somatosensory information, the sway-absent condition presents inaccurate somatosensory information and no vision, and the sway-sway condition presents inaccurate somatosensory and inaccurate visual information. The data obtained in the present study did not reveal any specific NeuroCom condition that was influenced differentially by the presence of the 30% load. As expected, based on results from previous studies, there was an overall decrement in postural control as a result of increased balance perturbation across the six conditions. These findings suggesting that the additional weight has a general effect on postural control and that the sensory strategies for organizing the visual, vestibular, and somatosensory components remained constant for young adults with additional load carriage.

Research using the dual task paradigm has provided evidence that attentional resources are used to maintain posture in addition to the components of the postural control system. The data obtained indicate that added balance perturbation does not disrupt cognitive performance when measured in terms of response speed. The speed which participants were able to hear and discriminate between stimuli within the same category (i.e., non-switch conditions: letter-letter; number-number) was not influenced by balance perturbation. Likewise, the speed which participants were able to hear and discriminate stimuli following a change in category (i.e., switch conditions: letter-number; number-letter) was not affected by weight load conditions. In the switch task, response times on non-switch trials are shorter than on switch trials. The difference in response times on switch and non-switch trials is explained in terms of response inhibition. Theorists suggest response inhibition is an executive process that influences an individual's ability to keep from making one response and to initiate a different response. The task-switching methodology provides a measure of the costs, in milliseconds, associated with switching from performing one discrimination task to performing a different discrimination task. In the present experiment, participants were instructed to switch from responding to letter stimuli to digit stimuli and vice versa. Comparing the response times on trials in which successive stimuli of the same category (e.g., two successive letters) and responses times on trials that change category (e.g., a digit stimulus followed by a letter stimulus) provide a measure of the cost associated with having to engage executive processes and shift response categories. The results obtained in the present study suggest that there was no difference in response time under the carriage load condition, which suggests that young adults are able to maintain the speed of executive processing and alter categorical judgments despite additional perturbation of balance. Executive processes are considered to reflect higher mental processes that are essential for maintaining attention, problem solving, and adaptation to complex environments.

The results obtained in the present study differ from those in obtained in a similar study conducted by Resch et al. (2008), which also employed a dual-tasking technique. They observed that both response time and response errors increased under several balance conditions. The lack of agreement may be explained in terms of methodological factors. The primary measure of dual-task interference was derived by Resch et al. (2008) by comparing participants' cognitive performance during a single-task condition and during a dual-task condition. Response times during dual-task conditions were longer than during single-task conditions, but only on switch trials. Participants also made more errors during dual-task conditions, but only on switch trials. In the present study, participants' balance was evaluated only under dual-task conditions. As a result, the magnitude of the effect of balance perturbation on participants' response time was smaller compared to the single-task and dual-task conditions employed by Resch et al. (2008).

There was a clear difference in the frequency of response-choice errors under the carriage load condition. The frequency of response errors depended on switch-task conditions. These findings are similar to those obtained by Resch et al. (2008); however, more response-choice errors were made during the non-switch condition than the switch condition in the current study. Further, it was found that concurrent with the carriage load the frequency of response-choice errors was greater during the non-switch trials than during switch trials. The increase in response-choice errors with increased postural instability in the present study and that of Resch et al. (2008) supports the "posture first," principle proposed by Kerr et al. (1985). He suggests that postural control is attentionally demanding and that demands increase with the complexity of the postural task being performed. Most likely, this relation is due to the need to incorporate the vestibular system opposed to solely visual and somatosensory stimuli during a complex cognitive task. (Vuillerme and Nougier, 2004). Vuillerme and Nougier (2004) suggest that allocating attention to a secondary task during upright stance could either reduce the attentional resources devoted to balance, thereby decreasing postural stability, or heighten subjects' alertness state, increasing postural stability. Since the current study found balance to only be altered by the presence of an additional load, the current study, like Resch et al. (2008) supports the latter.

The results obtained in the present study suggest that perturbation of balance leads to a speed-accuracy tradeoff in young adults. The speed-accuracy tradeoff is characterized by a shift in the criterion. Faster overall responses times result in an increase in error rate. Less error rate results in longer overall response times. Participants in the present study maintained response speed at the cost of accuracy. These results are important for understanding factors that influence military personnel's situational awareness. Military field performance requires the processing of multiple stimuli in order to perform efficiently. Behavior at any moment reflects the interplay between unconscious body-control systems and conscious decision-making processes. The dual-task paradigm employed by this study showed postural and cognitive changes under the influence of increased demands in balance in concert with a complex auditory task. The demands placed on the military personnel's systems by the load carriage, environmental demands, and cognitive tasks need to be taken into special consideration to reduce the likelihood of decision making errors.

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Appendix

Appendix A

Consent Form

Consent Form

I agree to participate in the research study titled, “Balance Demands and Cognitive Function”, which is being conducted by Dr. Phillip Tomporowski and Miss Bryson May of the Department of Kinesiology at the University of Georgia. I understand that this participation is completely voluntary; I can withdraw my consent at any time without penalty and have the results of my participation, to the extent that it can be identified as mine, returned to me, removed from the research records and destroyed.

The following points have been explained to me:

1. The research is being conducted to study the impact of wearing a weighted backpack during balance disruption on the cognitive functions of volunteers recruited from the UGA Army/ Air Force ROTC. Ultimately, this testing methodology will address, partially, the effects of environmental demands on military personnel’s’ situational awareness.

2. The procedures are as follows: I will receive a detailed explanation of the study, the benefits and risk of participation, and sign the informed consent. I will report to the Cognition and Skill Acquisition Laboratory for the inclusion of the study (Ramsey 106). I understand that I will be required to be tested on 3 separate occasions. I understand that each testing session will last approximately 45-75 minutes.

   Each testing session will consist of 2 parts: cognitive and motor assessment. The cognitive portion will be measured using an auditory switch task program in which I will have to respond to specific numbers and letters. My responses will be recorded using a computer program. The motor assessment will measure my balance using the NeuroCom Balance system.

3. The benefit that I may expect from this research is to expand the knowledge and understanding of dual tasking and its potential implications for field performance. At the conclusion of the study, I will receive information about my performance on the cognitive and motor task.

4. There is minimal risk of injury from my participation in this project. The only potential injury that may occur would be from a fall during the balance training or testing. However, the appropriate safety harness connected to the NeuroCom and trained spotters will be used to assist me in maintaining balance should I fall. In the event of injury resulting from participating in this project, immediate first aid is provided. If additional care is needed, I will be transported to the UGA Health Center (if I am a fees-paid student) or a local hospital of my choice and I will be responsible for any expense that may be incurred.

5. I fully understand my participation in this research study will not have any effects on grades or evaluations in class instructed by any of the investigators of this study.

6. The results of this participation will be confidential and will not be released in any individually identifiable form without my prior written consent, unless otherwise required by law. No data will be directly associated with the participant's name. Each data file will be marked with only a subject number. A master list linking the subject number to the subject name will be maintained until all data are collected, and it will be stored in a locked desk drawer in room 106C Ramsey Center. The master list will be destroyed once all data are analyzed, no later than 1 year following the termination of the project. All electronic data will be stored on a computer in Room 106 Ramsey Center. The locked room is accessible by keys held by the PI and investigators. Paper files (subject demographics) will be stored in a locked desk drawer in room 106C Ramsey Center. This room is assessable by key only by the PI and co-investigator. Each paper file will be marked only by the subject number and not the subject name.

7. The investigators will answer any further questions about the research, now or during the course of the project and can be reached at (706) 542-4183 for Dr. Tomporowski and (706) 542-6757 for Miss May.

I understand that I am agreeing by my signature on this form to take part in this research project and understand that I will receive a signed copy of this consent form for my records.

____________________	____________________	________________
Name of Researcher	**Signature**	**Date**

Telephone: _________

Email: _____________

____________________	____________________	________________
Name of Participant	**Signature**	**Date**

Please sign both copies. Keep one and return one to the researcher.

Additional questions or problems regarding your rights as a research participant should be addressed to The Chairperson, Institutional Review Board, University of Georgia, 612 Boyd Graduate Studies Research Center, Athens, Georgia 30602-7411; Telephone (706) 542-3199; E-Mail Address IRB@uga.edu